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DEVICE FOR CONVERTING THE IONIZING ENERGY, EMERGING FROM A NUCLEAR REACTOR, INTO ELECTRICITY

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DEVICE FOR CONVERTING THE IONIZING ENERGY, EMERGING FROM A NUCLEAR REACTOR, INTO ELECTRICITY

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For converting the ionizing energy, discharged by a nuclear reactor, into electricity, a device is described in which an electromotive force is created by keeping two hollow metal electrodes, in contact with mercury under vacuum, at different temperatures. Use of gases such as argon, neon, and helium which do not condense under the experimental conditions did not lead to the generation of an emf. A modified device, using a zirconium alloy bar in a UO_2-lined steel tube and floating in the heavy water of the reactor, was successful for direct conversion of the ionizing energy of fission products into electricity. Increase in electric power generated was obtained by using completely ionized cesium vapors and a heavier uranium oxide lining.

In previous publications (Bibl.1 - 10), we described the phenomenon of a direct conversion of ionizing energy into electricity, where the ionization was obtained either by a high-frequency electric field or by X-rays, or else by ionization chemistry.

Recently, we made experiments in a channel of the nuclear reactor EL.3 at

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** Numbers in the margin indicate pagination in the original foreign text.

Saclay, where the predominant ionizing agent consisted of fission products emitted by a thin uranium oxide layer. The experiments showed that, under these conditions, the conversion phenomenon also takes place.

We will briefly review the basic experiments which subsequently induced us to attempt tests in a nuclear reactor.

In a first experiment, a rather high electromotive force, accompanied by strong currents, was obtained by means of two electrodes placed along a mercury vapor jet ionized by high frequency, with the two electrodes being at different temperatures.

The important role played by the temperature difference of the electrodes in this particular phenomenon induced us to design the device schematically shown in Fig.1, in which no vapor jet was used. In fact, we raised the question whether the electromotive force might not be due to a transport of electric charges. The device in question consists of two hollow metal electrodes, inserted into a glass flask containing a certain quantity of mercury under vacuum. The /2 ionization of the mercury vapor again was obtained by a high-frequency field. The mercury itself is heated by an auxiliary heat source, placed underneath the glass flask. The overall unit thus acquires a temperature of several hundred centigrades.

Next, we varied the temperature of the electrodes. As soon as one of the electrodes is progressively cooled while the other is kept at 400° C, an emf up to several tens of volts is generated, with the cooler electrode being positive with respect to the hot electrode (Fig.2). As soon as the temperature of the cold electrode drops below about 150° C, the voltage becomes stabilized and the cold surface becomes coated with small mercury droplets.

In this phenomenon, the type of electrode is of no importance. In addi-

tion, no emf was observed whenever we used gases that did not condense under the experimental conditions, such as argon, neon, and helium.

So as to eliminate the high-frequency electric field, which might be suspected of influencing the separation of electric charges, we ran the experiments in flames in which a chemical ionization took place. The temperature effect, i.e., the temperature difference of about 250° C between the two electrodes, was again indispensable for generating a voltage and we actually measured currents of several tens of milliamperes at 1.8 v, in a flame whose electric conductivity had been increased by inoculation with potassium salts.

Other devices, which do not induce an electric field, were designed in which the ionization was obtained by soft X-rays. This yielded voltages of the order of 25 v.

In all cases, the cooler electrode is positive with respect to the other electrode, and we will demonstrate that the difference between the values of the emf observed when varying the mode of ionization can be attributed to the electronic temperature differences in the considered medium. In addition, the calculation apparently shows that the obtained currents are such that a large proportion of the charges present is collected.

A first test in a nuclear reactor channel EL.3 showed that it would also /3 be possible to convert the ionizing energy of fission products directly into electricity (Bibl.11).

Below, we will describe the experimental device, modified somewhat and used for a second test in the same channel (Fig.3). A bar of zirconium alloy of 20 mm diameter and 30 cm length is kept, by means of quartz insulators, at the center of a stainless steel tube of 50 mm diameter. This tube is lined with a very thin uranium oxide film (UO_2), enriched to 93% over the 30-cm sector facing

the bar. A small receptacle, also made of stainless steel, is attached to the base of this tube. The vessel is thermally insulated by alumina powder and is partially filled with heavy water. The other end of the tube is closed with a steel stopper, provided with an airtight alumina passage. Two thermocouples are used for measuring the temperature of the bar and that of the water. The thermocouple mounted to the bar also is used for measuring the emf. The entire apparatus is under vacuum.

This device, when introduced into the reactor, will swim in the heavy water of the latter. Because of this fact, the outer tube is cooled during operation of the reactor, since the temperature of the heavy water does not exceed 40° C. Conversely, the central bar is heated because of the radiations to which it is subjected.

This gave us a hot as well as a cold electrode, as in all of our previous experiments. The water, contained in the receptacle, also is heated and the entire enclosure becomes filled with water vapor which recondenses on the cold wall. These vapors are essentially ionized by the fission products emitted by the uranium oxide layer.

The variation in emf, collected at the terminals of the two electrodes, is plotted in Fig.4 as a function of the temperature of the hot electrode. Again, the cold electrode is positive with respect to the hot electrode.

Figure 5 gives the electric current discharged on a 100-Ω resistance, as a function of the reactor power. We made measurements up to 10 mw; within this power range, the electric current increases linearly.

At 10 mw, the maximum power is obtained as soon as the generator discharges across a resistance of 370 Ω. The current then is 3 ma at 1 v, which means that the magnitude of the power is 3 mw. /4

In a first estimate which, nevertheless, remains rather approximate because of the uncertainty as to the magnitude of the density of the vapors circulating within the generator, the maximum theoretically obtainable current under the experimental conditions could be calculated in the following manner:

As soon as the power of the reactor reaches 10 mw, the uranium oxide layer is subjected to a flux of 10^{13} neutrons/cm^2/sec. The temperature of the heavy water in the converter is 55°C, thus fixing the vapor pressure to approximately 100 mm Hg. The neutron flux generates 3×10^{10} fission products per cm^2 per sec. Each fission atom, at atmospheric pressure, creates on the average 10^6 ion pairs, i.e., 10^5 ion pairs at a pressure of 100 mm Hg. The surface of the layer is 450 cm^2. Consequently, the total number of ion pairs formed per second is 14×10^{17}, which corresponds to a current of about 200 ma.

This calculation is rather optimistic in view of the fact that the number of fission products, able to leave the emitting surface, is only one third of the total number of neutrons created, thus reducing the value of the maximum theoretical current to 60 ma. Thus, it seems that the measured current represents 10% of the available electric charges.

It is of interest to mention the following fact: At the very beginning of the experiments, when we were unable to define the temperature effect because of the fact that the bar had not yet been hot, and the power of the reactor was too low, we found voltages as high as 700 mv of variable polarity, accompanied by very weak currents.

It seems useful to postulate two theories that might explain the operation of the converter.

In both theories, the emf collected is considered as being the difference between the two floating potentials of each of the electrodes submerged in the

ionized vapor. This difference would be due to the rapid drop in kinetic energy of the negative electric charge carriers, in the vicinity of the coldest electrode.

To explain the differing values of the electronic temperature, A.von Engel and J.R.Cozens, using data relative to a flame, were able to demonstrate that /5 this difference can be attributed to the fact that the combustion rate is different in the vicinity of each of the electrodes and that, consequently, the number of excited atoms able to transfer kinetic energy to the electrons during inelastic collisions will be different there. Because of this, the values of the electronic temperature are rather high compared to the temperature of the flame (1700° C) and to the electronic temperature drop near the cold wall.

Since the generation of an emf can be observed only by means of vapors such as water vapors, cesium vapors, or mercury vapors that condense on the cold electrode, we believe that the negative charges are decelerated near the cold wall due to the formation of negative ions or of negative droplets. This causes the flux of charges near the cold wall to be composed of positive ions, of electrons, and of negative heavy particles whose motility is below that of the electrons. The floating potential of the cold surface thus is less negative than that of the hot surface.

The formation of negative ions or of negative droplets apparently is confirmed by the difficulty in interpreting measurements furnished by cooled electrostatic probes (Bibl.12).

In conclusion, returning to the results of experiments made with the nuclear reactor EL.3, we believe that the electric power collected can be increased by influencing the following factors:

1) The neutron flux can be readily increased to 5×10^{14} neutrons per

cm^2 per sec, i.e., to a value 50 times higher than that of the flux used in the preceding experiments.

2) The uranium oxide coating can possibly be increased by 2 mg/cm^2, i.e., by about five times, without preventing the fission products from traversing this layer.

3) The water vapor, whose ionization potential is 12.56 v, can be advantageously replaced by cesium vapor whose ionization potential is 3.87 v.

4) The pressure of 100 mm Hg at the inside of the device can be brought to atmospheric or higher pressure. /6

Finally, since it seems that the electric power available at the terminals of the generator increases proportionally with the density of the charges if a gaseous nuclear reactor in which almost the entire vapor is ionized can be designed, the obtained electric currents will be relatively high.

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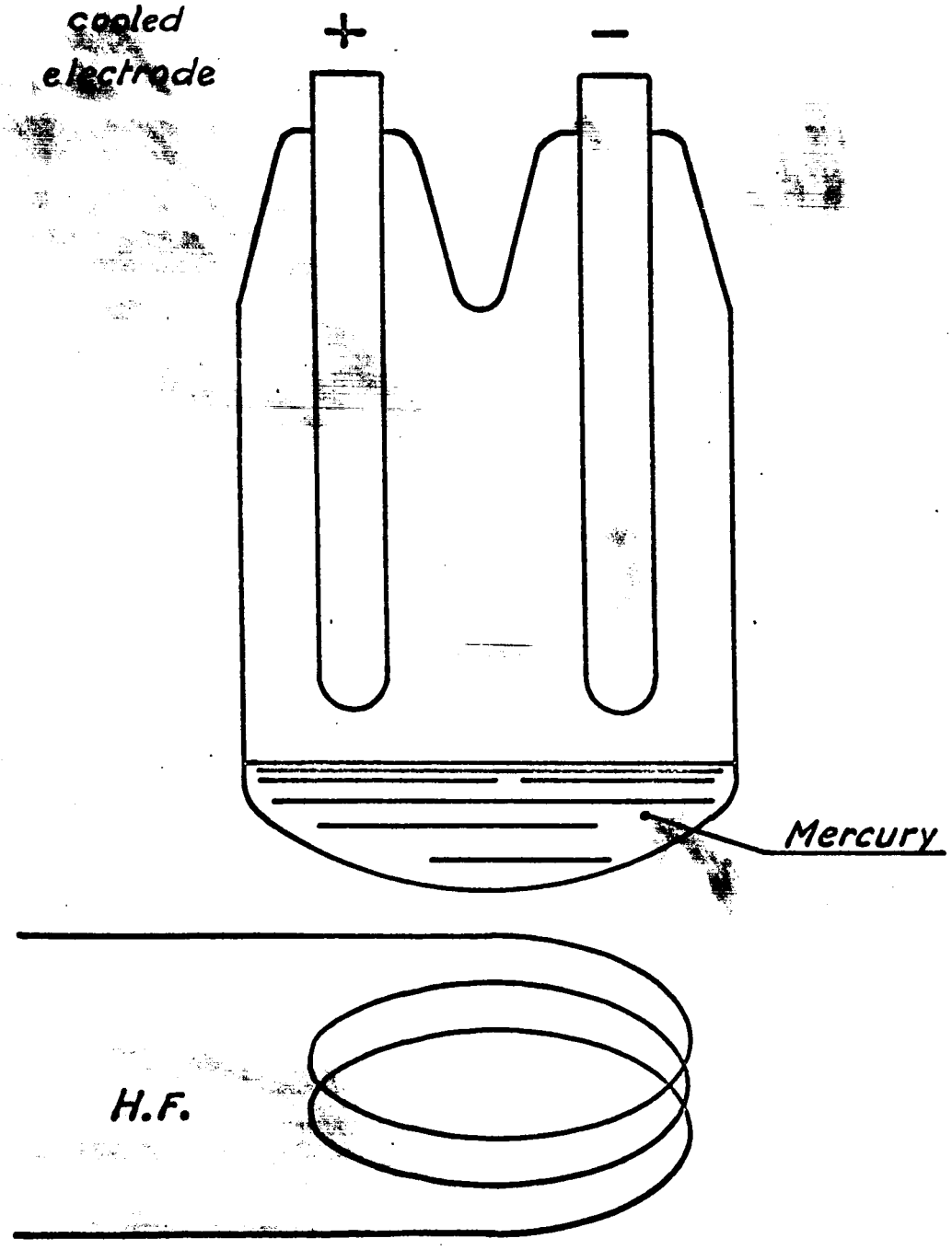

Fig.1

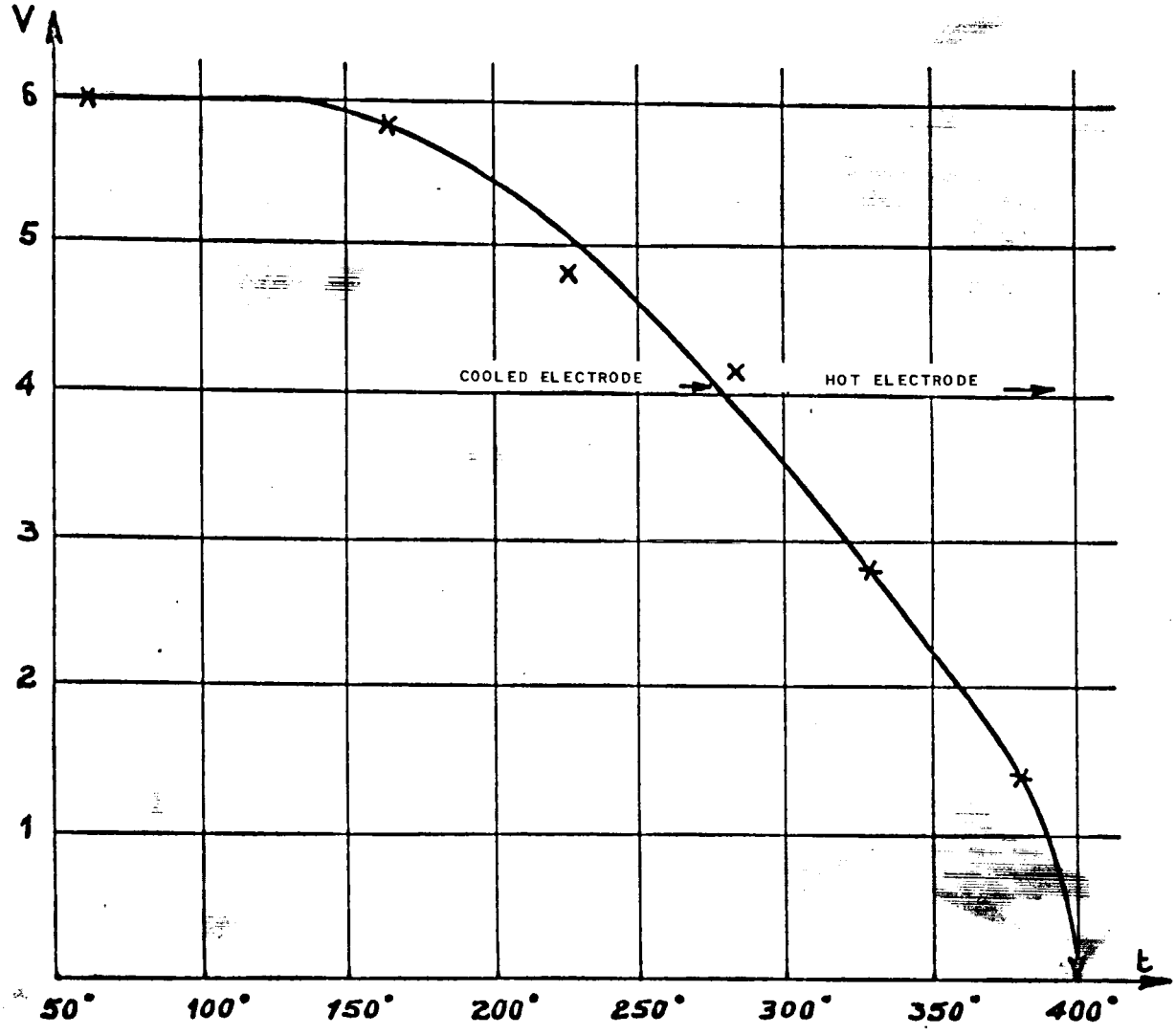

Fig.2 Voltage Curve as a Function of the Temperature Difference between the Electrodes

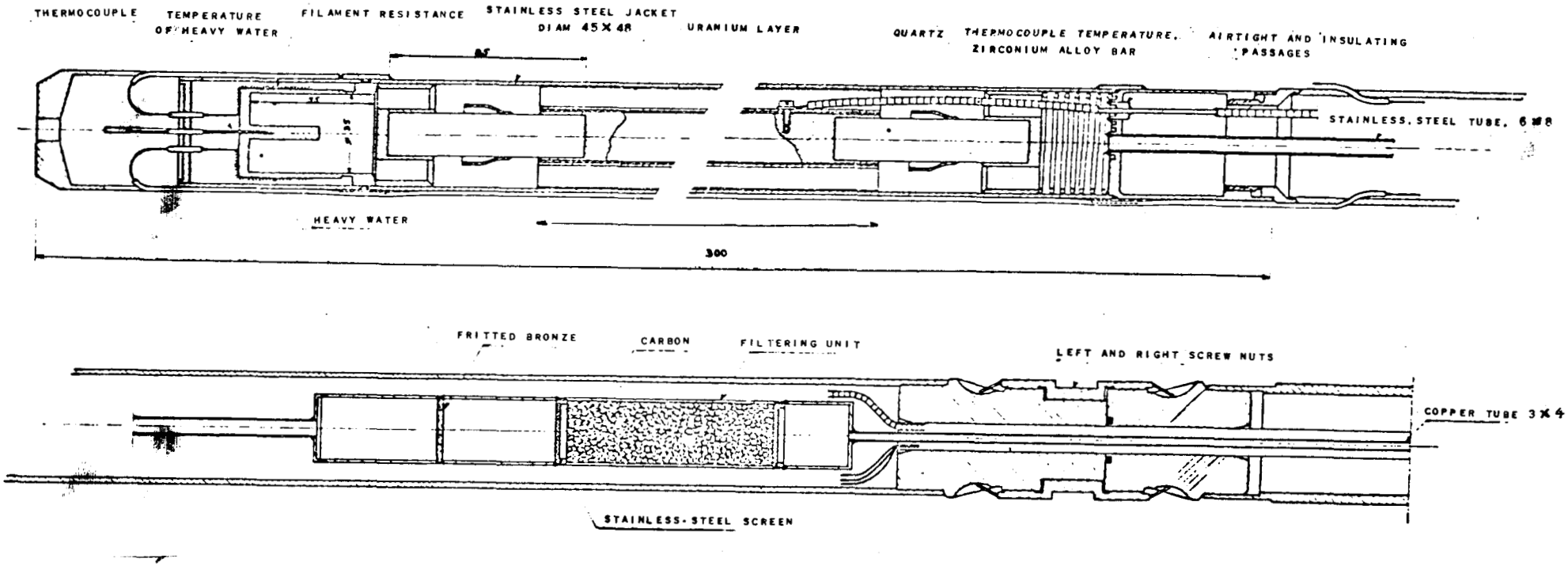
THERMOCOUPLE
TEMPERATURE OF HEAVY WATER
FILAMENT RESISTANCE
STAINLESS STEEL JACKET DIAM 45 X 48
URANIUM LAYER
QUARTZ
THERMOCOUPLE TEMPERATURE, ZIRCONIUM ALLOY BAR
AIRTIGHT AND INSULATING PASSAGES
STAINLESS STEEL TUBE, 6 X 8
HEAVY WATER
300
FRITTED BRONZE
CARBON
FILTERING UNIT
LEFT AND RIGHT SCREW NUTS
COPPER TUBE 3 X 4
STAINLESS-STEEL SCREEN

Fig.3

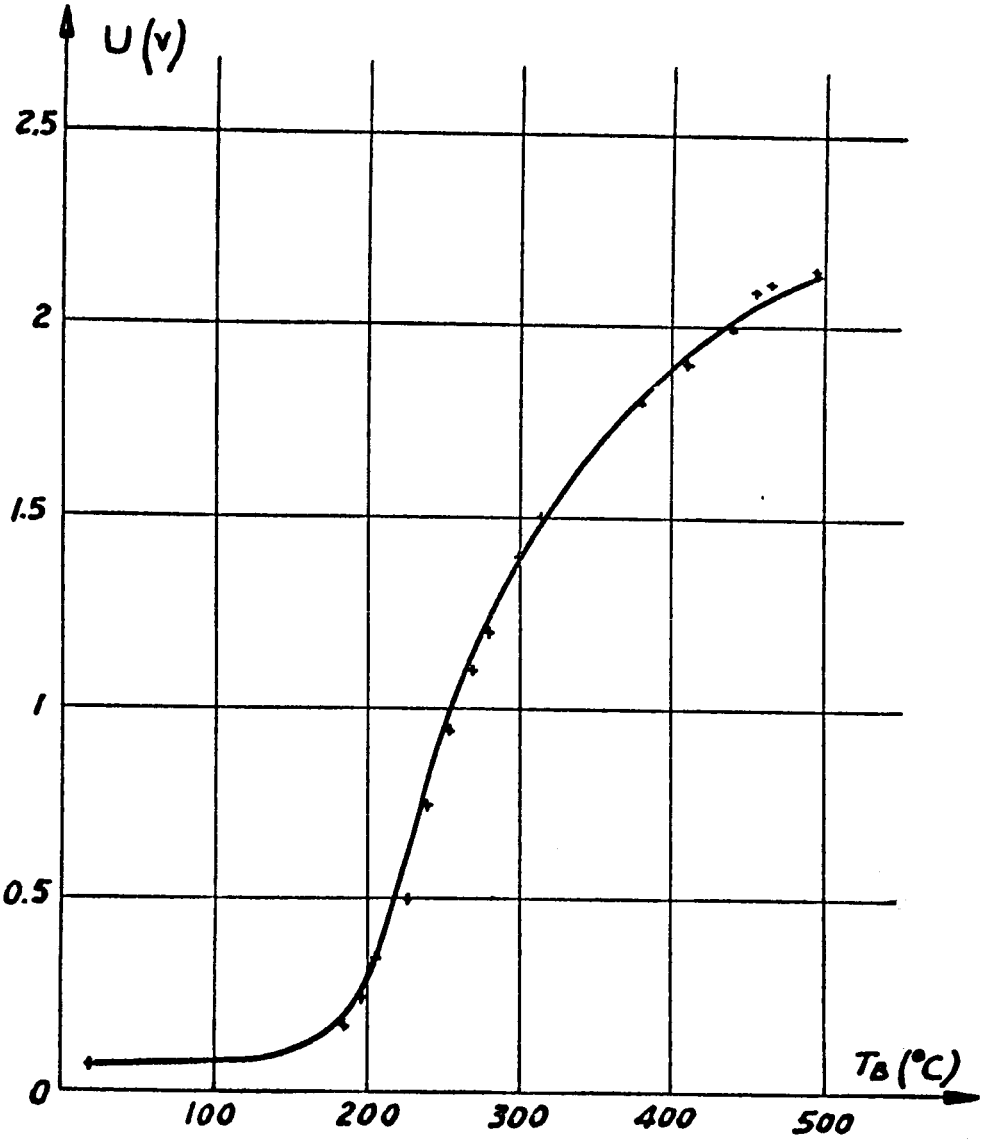

Fig.4

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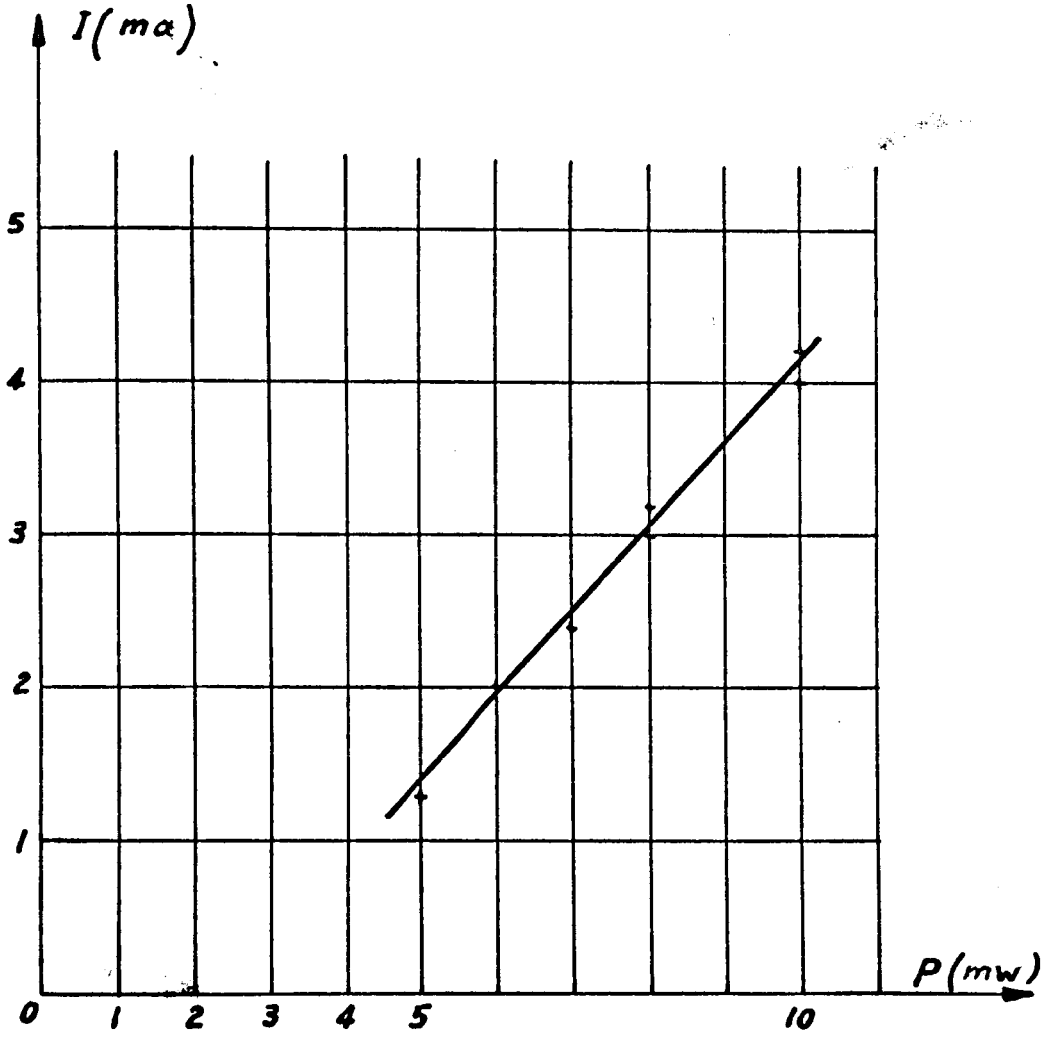

Fig.5